Application of Spacesuit Glove Requirements Tools to Athletic and Personal Protective Equipment

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INTRODUCTION

Despite decades of ongoing improvement, astronauts must still struggle with inhibited dexterity and accelerated fatigue due to the requirement of wearing a pressurized Extra-Vehicular Activity (EVA) glove [1]. Recent research in the Anthropometry and Biomechanics Facility at NASA's Johnson Space Center has focused on developing requirements for improvements in the design of the next generation of EVA glove. In the course of this research, it was decided to expand the scope of the testing to include a variety of commercially available athletic and consumer gloves to help provide a more recognizable comparison for investigators and designers to evaluate the current state of EVA glove mobility and strength. This comparison is being provided with the hope that innovative methods may help commercial development of gloves for various athletic and personal protective endeavors.

METHODS

For this investigation, three subjects completed hand strength and fingertip mobility tests while in seven gloved states. Gloves to be evaluated were pulled from various athletic and personal protective equipment fields, including a ski glove, hockey glove, baseball mitt, latex glove, leather work glove, and a 4000 series EVA glove. To minimize variability due to fit, subjects were selected who could fit well into a typical large glove, possessing approximately 70^{th} – 90^{th} percentiles of hand length and middle finger length.

Mobility

To evaluate the mobility of the gloves, retroreflective markers were attached to the tips of the index and middle fingers and in an array to the back of the subject's dominant hand in a method inspired by Kuo et al. [2]. Each subject then traced their index and middle fingers through three planar sweeps of their maximum range of motion (Figure 1) while kinematic data was collected at 100 Hz with a Vicon Motion Capture System (Oxford Metrics, Oxford, UK). The areas enclosed by the trajectory swept by the fingertips were calculated using a custom-written MATLAB script. The ratio from ungloved to each gloved state of fingertip areas provided a metric of degraded mobility attributable to the presence of the glove.

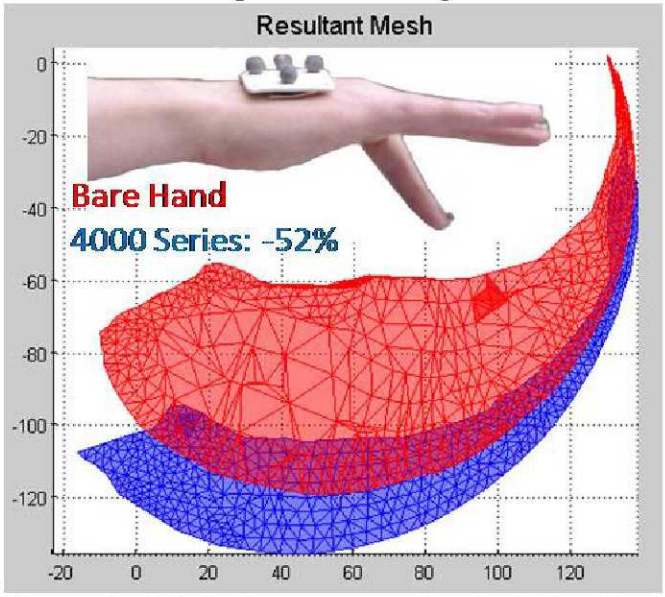

Figure 1: Meshed areas swept by the index finger while barehanded (Red/Above) and while wearing the 4000 series EVA glove (Blue/Below).

Strength

To evaluate the influence of gloved state on strength, the subjects exerted and sustained a maximal grip or pinch force for three seconds as force data was recorded at 1000 Hz. Subjects were given a two minute period to rest to avoid fatigue effects and then the measure was repeated three total times or until three consecutive maximum exertions fell within 10 percent of each other. Grip strength was recorded using a Jamar hand dynamometer (Sammons Preston, Bolingbrook, IL). Pinch strength was recorded using a calibrated force transducer in both a lateral pinch and pulp-2 pinch grip. The lateral pinch is representative of the posture one would use to hold a key while the pulp-2 pinch is formed by pressing the pads of the thumb and index finger together while fully extended.

RESULTS AND DISCUSSION

Inter-subject data was averaged to provide the relative performance of each glove. As expected, maximal fingertip mobility was observed in the bare hand case. The latex glove provided very nearly the full level of mobility, 91 % and 96 % of the barehanded area swept for the index finger and middle finger respectively. The worst performing glove for mobility was the baseball mitt, permitting just 16 % and 8 % of the barehanded mobility. Average mobility results for all gloves may be seen in Table 1.

Table 1: Mobility in Various Gloved States

	Area in mm^2 (% of Bare Hand)	
	Index Finger	Middle Finger
Bare Hand	9074 (100%)	10545 (100%)
Ski	7744 (85%)	8467 (80%)
Hockey	4083 (45%)	5094 (48%)
Baseball	1466 (16%)	885 (8%)
Latex	8264 (91%)	10174 (96%)
Leather	7540 (83%)	8377 (79%)
4000 Series	4347 (48%)	6900 (65%)

Changes in strength as a function of gloved state revealed some interesting fluctuations. It was expected that thinner gloves would minimally alter strength and bulkier gloves like the 4000 series EVA glove and baseball mitt would produce drastic reductions in strength. That was generally true for grip strength where the latex glove allowed 96 % of the bare hand grip strength and 4000 series EVA glove and baseball mitt reduced grip strength to 51 % and 37 % of the bare hand grip strength respectively. For lateral pinch and pulp-2 pinch strength, generally small reductions and in some cases increases in strength were observed (Table 2). The key pinch produced varied results depending on the purpose of the glove. Slight increases may be attributable to extra grip and padding on the bracing index finger. The lack of large reductions in pulp-2 pinch strength from the bare hand condition was surprising and may result from the gloves forcing hand posture into one giving subjects a mechanical advantage by bending the index finger and thumb.

Table 2: Strength in Various Gloved States

	Magnitude in lbf (% of Bare Hand)		
	Grip	Lateral Pinch	Pulp Pinch
Bare-hand	128 (100%)	28.1 (100%)	10.2 (100%)
Ski	101.9 (80%)	22.1 (79%)	11.5 (113%)
Hockey	86.1 (67%)	24.9 (89%)	11.5 (113%)
Baseball	46.8 (37%)	18.8 (67%)	9.4 (92%)
Latex	122.5 (96%)	29.9 (106%)	9.9 (97%)
Leather	96.8 (76%)	27.5 (98%)	10.6 (104%)
4000 Series	65.5 (51%)	26.2 (93%)	10.8 (106%)

These combined findings and methods may be useful in making future design decisions for gloves dependent upon their use, be it a one hour game, an eight hour EVA, or a 10 hour shift. Efforts to maximize functionality will benefit from refined methods to minimize degradation of mobility and strength.

CONCLUSIONS

The strength and mobility data showed interesting trends in the relative performance of gloves designed for very different purposes. These methods may be modified and applied to improve the capabilities of additional gloves, be they for athletic or protective purposes.

REFERENCES

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ACKNOWLEDGEMENTS

The authors wish to thank the Constellation EVA Project Office for funding this work.